Exploring the financial and investment implications of the Paris Agreement

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Abstract

A global energy transition is underway. Limiting warming to 2°C (or less), as envisaged in the Paris Agreement, will require a major diversion of scheduled investments in the fossil-fuel industry and other high-carbon capital infrastructure towards renewables, energy efficiency, and other low or negative carbon technologies. The article explores the scale of climate finance and investment needs embodied in the Paris Agreement. It reveals that there is little clarity in the numbers from the plethora of sources (official and otherwise) on climate finance and investment. The article compares the US$100 billion target in the Paris Agreement with a range of other financial metrics, such as investment, incremental investment, energy expenditure, energy subsidies, and welfare losses. While the relatively narrowly defined climate finance included in the US$100 billion figure is a fraction of the broader finance and investment needs of climate-change mitigation and adaptation, it is significant when compared to some estimates of the net incremental costs of decarbonization that take into account capital and operating cost savings. However, even if the annual US$100 billion materializes, achieving the much larger implied shifts in investment will require the enactment of long-term internationally coordinated policies, far more stringent than have yet been introduced.

Policy Relevance Statement

Maintaining momentum towards fulfilling Article 2 of the UNFCCC – avoiding dangerous climate-change – means keeping a sense of perspective on how key financial and investment indicators of progress relate to the underlying macroeconomic reality of the task that lies ahead. There is a wide gap between the level of rhetorical commitment to mitigating and adapting to climate change evident at the Paris COP 21 Climate Summit, and countries' actual on the ground commitments to emission reduction and investment in climate resilience, and the policies to bring them about. In particular, major shifts in financial flows towards low-carbon energy (renewables and energy efficiency) will be required if this gap is to be reduced.

Keywords

Climate Finance; Climate Investment; Green Growth; Paris Agreement.

1. Introduction

The Climate Change Conference in Paris in December 2015, known as COP21 (the 21st Conference of the Parties under the UN Framework Convention on Climate Change, UNFCCC) arrived at an agreement (the Paris Agreement) to keep average global warming well below 2°C. A number of new studies were published in the run up to COP 21 that included headline figures relating to climate finance and investment needs. There is considerable and longstanding debate over the climate finance and investment needs that would be needed to achieve this aim. Indeed, studies of the optimal cost of climate stabilisation strategies offer a wide range of uncertainty reflecting differences in models, methods and economic assumptions. The decision adopting the Paris Agreement reconfirmed the existing commitment of the international community to mobilise $100 billion a year in assistance for developing countries, but this is only one estimate, and does not cover the full scope of climate finance, with that scope itself contested. Perhaps the only fact on which the literature is agreed, is that there exists a large climate finance "gap" – a gap between current climate-friendly financial flows, and those that would be needed to achieve long term climate stabilisation goals (Bowen, Campiglio, & Herreras Martinez, 2015; Fankhauser, Sahni, Savvas, & Ward, 2016; Haites, 2011; Olbrisch, Haites, Savage, Dadhich, & Shrivastava, 2011). There are shorter-term 'specialized' climate-finance gaps (e.g. up to 2020; World Bank, 2015) as well as longer-term cumulative climate-related investment/incremental investment gaps (e.g. 2010–2050; McCollum et al., 2013).

Studies of the optimal cost of climate stabilization strategies offer a wide range of uncertainty reflecting differences in models, methods, and economic assumptions.

The US$100 billion target contained in the Paris Agreement is only one estimate of climate-finance requirements, but there are many others with which it may usefully be compared (Zadek, 2011). In the run-up to and since COP 21, a number of new studies were published that included headline figures relating to climate finance and investment needs. This paper reviews the nature and scale of these new estimates as well as other existing literature, in order to explore the financial investment implications of achieving the 2°C target.

In this article, we triangulate some key numbers of climate finance and investment from different sources, as a reality check on the scale of the political and policy challenges ahead. We provide some historical background to the meaning and scale of the term 'climate finance' and climate investment in the context of the UNFCCC, consider some recent shifts in perceptions about the prospects of this finance becoming available and explore the kinds of policy measures that will be required for this to be the case.

2. Climate-related finance and investment.

Financing climate action has always been a critical part of the politics of the climate negotiations since their inception. One of the earliest attempts in the climate negotiations to quantify the scale of public and private climate-related finance arose in the context of tracking Parties' commitments to the issue of development and transfer of technologies (UNFCCC, 2008). Climate finance has grown in the years since then, most markedly since 2011. At the same time, the initial emphasis on finance for capacity building and mitigation projects has been re-balanced towards a more even balance on mitigation and adaptation policies, measures, and technologies.

Under the UNFCCC 'climate-finance' has evolved from an initial phase with an emphasis on short-term and relatively modest flows to a second phase with an emphasis on longer-term and more substantial flows. In phase 1 (1994–2009) it referred to 'funding' (rather than *finance*) in relation to several agenda items regularly discussed under the Convention. These included: adaptation (initially very small amounts), transfer of technology, mitigation, national communications and capacity building. Article 11 of the UNFCCC established a 'Financial Mechanism' that is entrusted to the Global Environment Facility (GEF) along with other 'international entities'. Phase 2 (2009–the present) is characterized by an emphasis on 'long-term finance' involving specified financial targets and timetables (e.g. 2014–2020).

The Copenhagen Accord (COP15, 2009) marked the start of phase 2 and coined the term 'climate finance' when developed countries made a pledge:

- 'to provide new and additional resources, including forestry and investments through international institutions, approaching USD30 billion for the period 2010–2012 with balanced allocation between adaptation and mitigation'; (sometimes referred to as Fast Start Finance) and

- 'to a goal of mobilizing jointly USD100 billion dollars a year by 2020 to address the needs of developing countries. This funding will come from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources of finance' (UNFCCC, 2010, para 8).

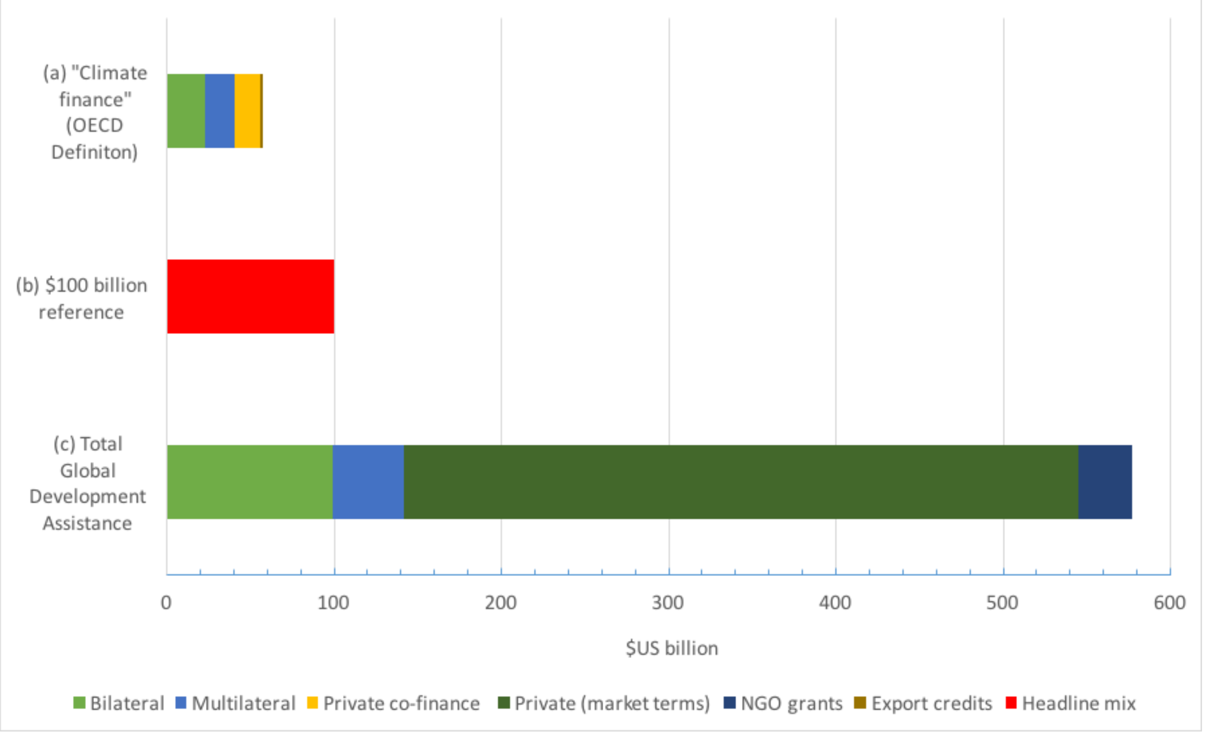
A Green Climate Fund was then established in 2011 (COP 17) as an entity under the Financial Mechanism. Several specialized (dedicated climate) funds were already established including: the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LDCF) managed under the Convention; and the Adaptation Fund (AF) managed under the Kyoto Protocol, launched in 2001.

The US$100 billion has since become a key policy reference point. It is the current scale at which, in terms of climate finance, the international climate negotiations function (e.g. OECD, 2015).

To facilitate the monitoring of long-term financing under the Convention, a Standing Committee on Finance was established at COP 16 in 2010. In line with the UNFCCC Standing Committee on Finance's recommended operational definition, climate finance includes 'all finance that *specifically* [emphasis added] targets low-carbon or climate-resilient development' (OECD, 2015, p. 10). Climate finance reached US$62 billion per year in 2014, up from US$52 billion per year in 2013 (equivalent to an annual average over the two years of US$57 billion – Figure 1(a)) (OECD, 2015). These amounts include 'finance from a variety of sources, public and private, bilateral and multilateral, including alternative sources of financing, to support climate change adaptation and mitigation actions in developing countries'. The largest share, however, was public finance (Figure 1(a)).

The US$100 billion (Figure 1(b)) is also, according to the OECD, the same order of magnitude as the total *public* development assistance budget from all donors to all recipients for all causes in 2014 (around US$140 billion – Figure 1(c) green and light blue bars). Total net financial flows (including market-driven private flows) are considerably greater bringing the overall total close to $US 600 billion in 2014 (Figure 1(c)).

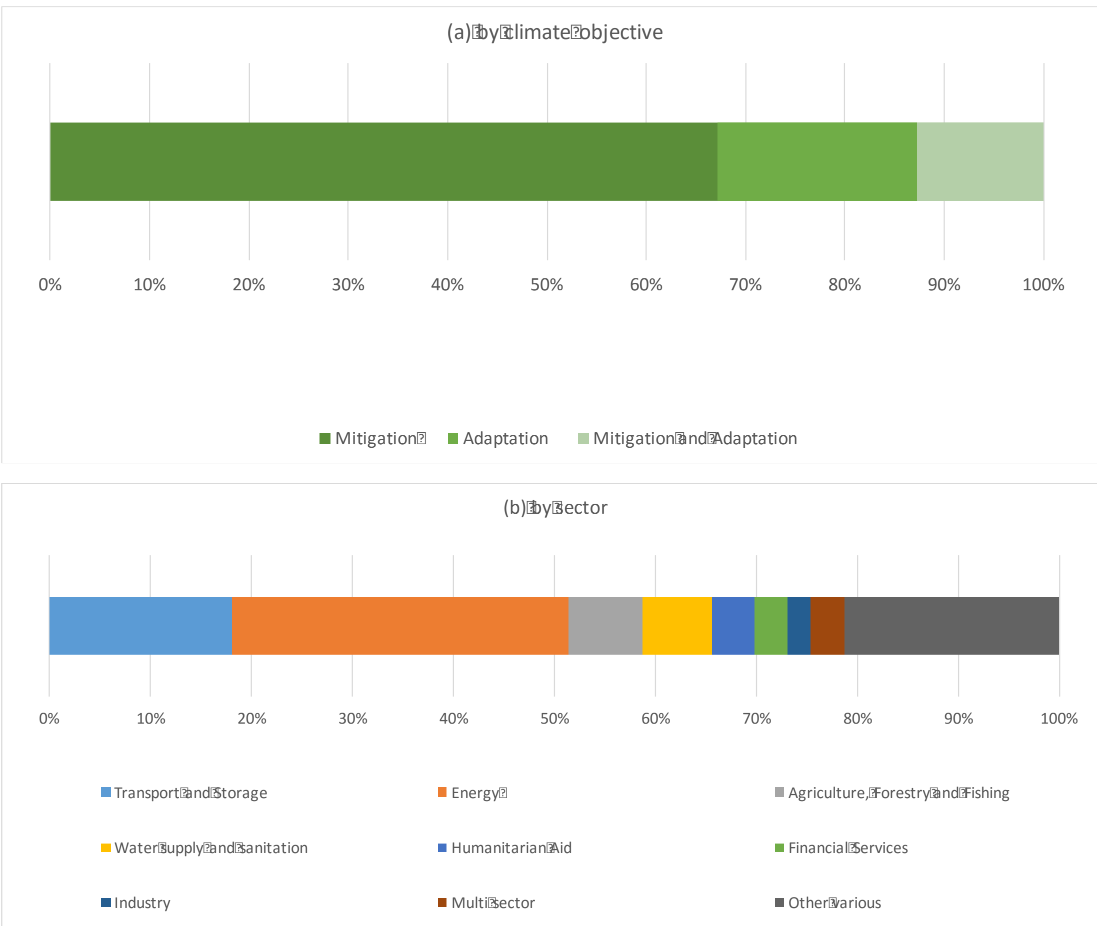
Figure 1: The scale of (a) OECD defined "mobilized climate finance flows" relative to (b) the US$100 billion reference and (c) total (public and private) global development assistance in 2014



sources: (a) OECD, 2015 (b) OECD, 2016a

Development assistance serves multiple policy objectives. Filtering financial flows to isolate 'climate-related' projects involves a high degree of methodological uncertainty. 'Climate' is a bundled, multifaceted label (from energy to human health, sanitation, and agriculture). Labelling development assistance in this way is not a straightforward accounting practice and can be methodologically challenging as finance projects can have multiple objectives (e.g. Michaelowa & Michaelowa, 2011a). It is possible that some of the 'growth' in climate-related finance and investment could be a reallocation and/or relabelling of existing aid flows (e.g. Michaelowa & Michaelowa, 2011b). Nevertheless, a proportion of this ODA is officially marked as 'climate-related' (despite methodological uncertainties). Total commitments on bilateral and multilateral climate-related development finance commitments (from OECD Development Assistance Committee members, Multilateral Development Banks (MDBs), and the GEF) in 2014 amounted to approximately US$39 billion (according to a recipient perspective), the majority of which was for mitigation projects (Figure 2(a)). Around two-thirds of this annual US$39 billion is for energy-, transport- and storage (logistics)-related projects (Figure 2(b)).

Figure 2: Breakdown of climate related development finance (a) by climate objective and (b) by sector



Source: OECD, 2016b

Monitoring, reporting, and verification of climate finance is an administratively complex accounting challenge, often characterized by double counting, definitional complexity, and methodological incompleteness (Stadelmann, Michaelowa, & Roberts, 2013), resulting in opacity and inconsistency. Assessing and evaluating financial flows in such circumstances are challenging. The following are some of the general sources of methodological uncertainty when attempting to understand estimates of climate finance:

- Separating finance directed towards mitigation versus adaptation (climate resilience), or both;
- Accounting for project additionality (the emission reduction below some baseline that occurred because of the project, and the part played by the climate finance in this);
- Double counting (between different climate funds);
- Double counting (markers within funds, e.g. distinguishing between principal climate-related objectives versus other secondary benefits to sustainable development);
- Accounting for incremental costs: usually the full value of the financial flow is captured and not the share associated with the climate-change benefit;
- Industry association views versus independent estimates of financial flows (in part explained by data sensitivity and confidentiality);
- Accounting for the general lack of data on national public expenditures. UNFCCC notes that there is 'very little data on national public expenditures for climate-change activities, in both developed and developing countries. With the exception of bilateral and multilateral flows for the energy sector, and private sector finance for renewables, there is relatively little data on which to base a significant trend';
- Accounting for public/private interactions. There are various proxies for 'mobilized finance'. Mobilized finance refers to quantifying the effect of public interventions aimed at mobilizing private finance for climate activities. It is technically complex and challenging to measure (Jachnik, Caruso, & Srivastava, 2015; UNFCCC, 2014).

Records of finance flows are not nearly as developed or consistent as data on national emissions, for example. UNFCCC (2014) comment on the overall integrity of information relating to climate finance:

None of the global institutions that aggregate or produce data used in this report provide an estimate of the level of accuracy associated with their data. At best, they provide a range and *the underlying assumptions and methodologies to help the reader understand how they come up with their estimates.* (UNFCCC, 2014, para 223, pp. 84–85)

The Standing Committee on Finance conducted its first Biennial Assessment and Overview of Climate Finance Flows in 2014 (UNFCCC, 2014). It provides an estimate of finance flows of 2010–2012 (Table 1). The report distinguishes:

- Public and Private 'global climate finance' data which includes public and private financial resources devoted to addressing climate change globally; and
- Flows from developed to developing countries aimed at addressing climate change, which includes climate finance reported to the UNFCCC.

Table 1 shows that the changes in financial flows necessary to bring about the low-carbon energy transition have tentatively begun. Prior to the Copenhagen COP 15 in 2009, only relatively small amounts of finance (in the order of US$ tens of billions) were on the UNFCCC negotiating table. These were mostly directed to capacity building to develop, for example, national communications, pilot mitigation projects through the financial mechanism of the Convention (the GEF, operated by the World Bank). As a project mechanism, the Clean Development Mechanism (CDM) was exceptional in mobilizing more than US$200–300 billion in investments (largely in renewable energy) in developing countries over a decade (UNFCCC, 2014, p. 36).

Table 1: estimates of annual global climate finance flows in the period 2010-2012

Category/Sub Category*	US$ billion per year
Global total climate finance (Estimates of global total climate finance include both public and private in both developed and developing countries and including adjusted estimates of energy efficiency investment. This estimate is highly uncertain)	340-650
All financial flows from developed to developing countries (including both public and private flows of finance)	40-175
Flows to developing countries through public institutions	35-50

Other official flows ((a) grants or loans from the government sector not specifically directed to development or welfare purposes and (b) loans from the government sector which are for development and welfare, but which are not sufficiently concessional to qualify as ODA. These flows are channelled through bilateral channels (e.g. IDFC members, OPIC)	14-15
MDB finance (MDB flows are adjusted to exclude external resources managed by MDBs and funding to economies in transition/developing countries.)	15-23
Climate related ODA (Bilateral ODA flows are adjusted to exclude funding through multilateral climate funds to reduce double counting).	19.5-23
Multilateral climate funds	1.5
UNFCC funds (Funds accountable to the UNFCCC COP including the GEF, LDCF, SCCF, and the Adaptation Fund)	0.6

Source: UNFCCC (2014:7): * The sub-categories are not mutually exclusive and therefore some amounts overlap.

The reference US$100 billion number is both a relatively large *and* small number in relation to the 2°C agreement. An additional ('new money') US$100 billion per year of climate finance by 2020 would significantly increase climate financial flows over this period. It would be the equivalent of a 70% increase in the current total ODA budget, or a quadrupling of all current adaptation finance flows. The US$100 billion number corresponds to one of the early estimates of the costs to developing countries of adaption to climate change (Parry et al., 2009). More recently, some estimates of adaptation finance needs by 2030 have trebled up to US$300 billion per year (UNEP, 2016, p. vii). However, relative to overall general baseline cumulative investment in the global economy (e.g. the US$ trillions of capital expenditure over the coming decades scheduled on infrastructure, including energy, transportation, water, and sanitation systems), US$100 billion is a small number (IPCC, 2007, and see below).

Climate finance is required for both mitigation and adaptation projects/investments – i.e. for low-carbon (mitigation) and climate-resilient (adaptation) development (e.g. UNFCCC, 2014, para 59, p. 33). The climate finance flows required by the Paris Agreement can be compared with (a) estimates of business as usual investment flows in energy-related and adaptation/climate resilience infrastructure systems and (b) estimates of incremental (additional) flows that might be required to meet climate goals.

It is important to consider the relative scale of climate finance in relation to estimates of climate investment needs. In general, estimates of investment needs in the areas of mitigation and adaptation are the product of fairly rudimentary methods and assumptions. One study of investment needs across the Sustainable Development Goals (SDGs) noted that such methods are least well developed in the areas of environment, energy, and climate (Schmidt-Traub, 2015).

An indirect way of scaling investment needs is to start with the scale of economic growth. For the last 50 years, real global GDP (PPP) has grown at a steady annual average rate of 3.8% and in 2014 was approximately US$78 trillion (World Bank, 2016).

Average annual GDP growth is currently around 3–4% (2013–2016). The global economy is therefore currently growing by around US$2.3–3.1 trillion (current) per year. According to one projection by the OECD, global GDP is expected to grow at around 3% per year over the next 50 years, but wide variations are forecast between countries and regions (OECD, 2012).

A key component of the increase in global GDP is the net increase in Gross Fixed Capital Formation (GFCF) in the form of assets such as energy, water and waste systems, and infrastructure. The long-term success of achieving the Paris Agreement will be determined by the proportion of GFCF that is low carbon (e.g. renewable energy and energy efficiency) and/or climate resilient (e.g. cities that can function productively into the future against a back drop of regional temperature increases of, for example, 1–3°C by 2070). Rates of GFCF vary widely between countries (from around 5–40% of GDP: World Bank, 2014). New Climate Economy (NCE, 2014) estimates overall cumulative global fixed capital formation over 2015–2030 at US$400 trillion, or US$27 trillion per year based on historic trends and future GDP forecasts (Table 2). The incremental low-carbon and climate-resilient components of GFCF are, by definition, a fraction of this overall figure.

Table 2: Annual and periodic estimates of current and future annual cumulative and incremental investment flows

Source	**Year/ Period**	**Estimate type**	**Estimate details**	**Average annual investment over period (US$ trillion)**
World Economic Forum (WEF, 2013)	2014-2020	Investment	Capital investment in infrastructure of all kinds (water, agriculture, telecoms, power, transport, buildings, industrial and forestry sectors).	5.0
World Economic Forum (WEF, 2013)	2014-2020	Incremental investment	Additional, incremental investment needs of at least US$ 0.7 trillion per year to meet the climate-change challenge.	0.7
UNCTAD (2014) cited in OECD (2016c) Development Cooperation Report	2015-2030	Investment	Investment needs for the Sustainable Development Goals	Globally: 5.0-7.0 In Developing Countries: 3.3-4.5
The Global Commission on the Economy and Climate, New Climate	2015-2030	Investment (GFCF)	Estimate of US$ 400 trillion of new investments will be made into fixed capital formation based on historic trends and future GDP forecasts.	$27

Economy Project, 2014 Report (NCE, 2014).	2015-2030	Investment	Cumulative global investment in infrastructure (chiefly in “energy and cities”) in the period up to 2030 $ 89 trillion	$6.0
	2015-2030	Investment	Cumulative global investment in energy infrastructure $33.8 trillion baseline + 11.2 (incremental to achieve climate goals).	$3.0
	2010	Investment	Global construction spending on buildings of the order of US$5.4 trillion (in constant 2005 US$).	$5.4
	2015-2030	Incremental investment	Overall, the net incremental infrastructure investment needs from a low-carbon transition could be just US$ 4.1 trillion	$0.27
IEA, 2015 (new policies scenario)	2015-2040	Investment	Total energy sector investment (high and low carbon investments including both energy supply and energy efficiency): U$ 68 trillion (2014 dollars)	$2.7
Bloomberg New Energy Finance (2016)	2015	Investment	2015 clean energy investment (all asset classes all clean energy sectors) was US$ 330 bn	$0.33
UNEP (2016)	2015-2030	Incremental investment (adaptation)	adaptation finance needs by 2030	$0.1 rising to $0.3 by 2030

In 2013, the World Economic Forum (WEF) estimated capital investment in the water, agriculture, telecom, power, transport, buildings, industrial, and forestry sectors to meet global population and economic growth to be US$5 trillion per year in the period up to 2020, of which the additional, incremental investment to meet the climate-change challenge was US$0.7 trillion per year. The Global Commission on the Economy and Climate has estimated the overall scale of investment in infrastructure (mainly energy and cities) in the period up to 2030 at around US$90 trillion (NCE, 2014). The energy component is divided into approximately US$2.25 trillion per year baseline and an incremental climate-change component of US$0.75 trillion per year. Estimates of energy-related capital investments required have grown significantly over the last decade. The IPCC Fourth Assessment Report (IPCC, 2007), for example, estimated that future energy infrastructure investment would amount to just US$20 trillion between 2005 and 2030. In contrast, according to the IEA's 2015 World Energy Outlook, world energy sector investment in its New Policies Scenario totals US$68 trillion, or US$2.7 trillion per year from 2015 to 2040. In the WEO 2015 estimate 37% is in oil and gas supply, 29% in power supply and 32% in end-use efficiency. Renewables account for more than 60% of additional investment in power generation capacity in the New Policies scenario (led by China, the European Union, the United States, and India).

Most of the estimates of overall and energy-related infrastructure requirements for the low-carbon transition are based on simple arithmetic models. The UNFCCC notes, for example:

For the last twelve years, the IEA has undertaken an annual survey of energy use by sector (transport, industry, power and residential) to determine the annual energy demand and types of equipment purchased in developed countries and Brazil, Russia, India, China and South Africa (BRICS) ... The methodologies used by the IEA and the underlying assumptions suggest that their modeling and estimation is more relevant for insights rather than accuracy. (2014, p. 30, para 41)

Bloomberg New Energy Finance (BNEF, 2015) estimated that clean energy investment was US$329 billion in 2015 (it has been at or around the US$300 billion per year mark since 2012). This investment is roughly equally split between OECD and non-OECD countries.

Estimates of future business-as-usual infrastructure investment requirements to realize GDP and population growth forecasts vary widely in the literature (Table 2), as do the incremental climate change-related components. The various investment estimates are tabulated in Table 2, and presented graphically in Figure 3.

Figure 3: Various estimates of climate investment (energy and adaptation) flows compared with the $US 100 billion reference.

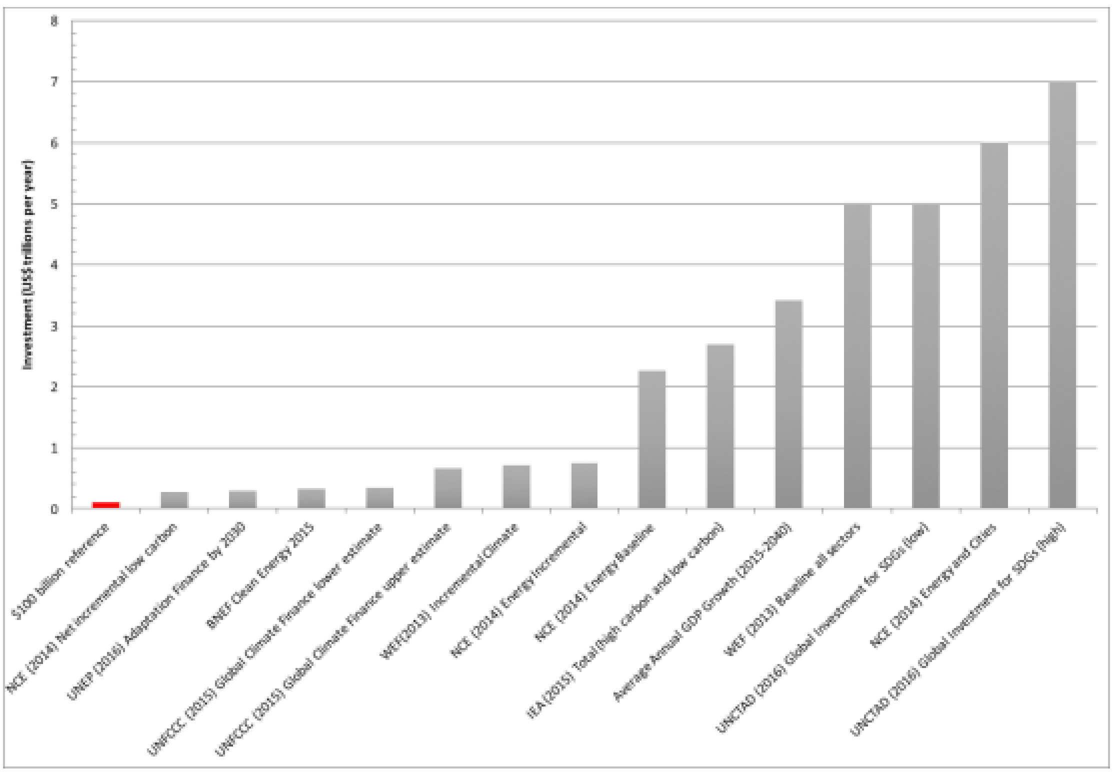


Figure 3 shows that, notwithstanding uncertainties and different estimates, total climate-related financial flows will need to be considerably larger than US$100 billion if the aspirations in the Paris Agreement are to be met. The US$100 billion is intended as a target that would help countries (particularly least developed countries) mitigate and adapt where they otherwise might not be able to do so.

By contrast, according to the Carbon Tracker Initiative (2015), a total of US$2.2 trillion of fossil-fuel-related capital expenditure up to 2025 needs *not* to be approved in order to avoid around 156 $GtCO^2$ of emissions and remain consistent with a 50% chance of meeting the UN 2°C trajectory. The breakdown includes: thermal coal – over the next decade, capital expenditure of US$215 billion on new and existing projects unneeded; oil – spending of US$1.427 billion on new and existing projects unneeded; gas – capital expenditure of US$532 billion on new and existing projects unneeded. These amount to a total of US$0.21 trillion unneeded capital per year over the period.

Table 3 compares the estimates in Table 2 and Figure 3 with the US$100 billion negotiation number, expressing the difference as a multiple of the US$100 billion figure.

Table 3: Scale of the climate investment challenge (factor multiples of the US$100 billion per year climate finance policy goal).

Investment estimate	**Factor multiple of US$ 100 billion**
Estimated investment in GFCF based on historic trends (NCE, 2014)	270
Average annual global investment needs to meet the sustainable development goals (UNTAD, 2016)	50-70
Average annual estimated investment required in infrastructure of all kinds (WEF, 2013)	57
Average annual estimated investment required in energy infrastructure of all kinds (IEA, 2015)	27
Average annual Global Climate Finance 2010-2012 (public and private) (UNFCCC, 2014)	3.4-6.5
Average current investment in clean energy (BNEF, 2015)	3
Incremental adaptation annual investment needs by 2030 (UNEP, 2016)	3
NCE (2014) Net Incremental Low Carbon Transition	3

Average rate of potentially stranded assets in fossil fuel sector (CTI, 2015)	2
Global total Overseas Development Assistance, 2014 (OECD, 2016a)	1.4
The Paris Agreement US$100 billion	1
OECD 2015 estimate of mobilized (public + private) climate finance (OECD, 2015)	0.6

Table 3 shows that, compared to the Paris US$100 billion climate-finance target:

- Global annual fixed capital formation is of the order of 270 times larger;
- Global investment needs to meet the SDGs is of the order of 50–70 times larger;
- Global investment in energy infrastructure is of the order of 27 times larger.

Some types of climate finance are capable of leveraging investment. However the difference in scales between near-term climate finance and future climate investment needs shown in Figure 3 suggests there remains a significant climate finance gap.

3. The green growth opportunity.

Next, we explore the overall economic and welfare impacts of these climate-related investment flows. When deciding how to allocate the emission reductions for 2008–2012 required under the Kyoto Protocol, the EU Emission Trading System (EU ETS) spoke explicitly of 'burden sharing' and 'effort sharing'. The Stern Review on the Economics of Climate Change (Stern, 2007) stimulated a wider and deeper debate in the economic and scientific literature on the costs of mitigation in the run up to the IPCC's Fourth Assessment Report (IPCC, 2007). One meta-analysis of the range of modelling results for mitigation costs for stabilizing GHG gas emissions at 500 ppm gave results for the costs of deep decarbonization mainly in the range of 1–4% GDP (Barker, Qureshi, & Köhler, 2006; cited in Stern, 2007, p. 270). These studies typically did not model the benefits of avoided climate damage or the co-benefits of mitigation measures, in terms of the reduction of the external costs of fossil-fuel use, discussed further below. The Stern Review estimated that the potential costs of damage for climate change, up to 20% of global GDP, were far in excess of those of climate-change mitigation.

Around the same time, a new discourse was also emerging in the business world around the framing of natural and regulatory risk multipliers, including climate change (e.g. Dobbs, Oppenheim, Thompson, Brinkman, & Zornes, 2011). Record fossil-fuel prices and the 2008 global financial crisis further propelled the concept of green growth up policy agendas (for example, see OECD, 2011). This was then linked to increases in resource productivity of factor 4 (von Weizsacker, Lovins, & Lovins, 1998)/factor 5 (von Weizsacker, Hargroves, Smith, Desha, & Stasinopoulos, 2009) and factor 10 that had emerged a decade earlier.
In the lead up to the financial crisis, the oil price had been persistently above US$ 50/bbl since the start of 2005 and had climbed steadily, peaking at a record US$ 147/bbl in July 2008. The IEA began to speak of an energy revolution that is 'necessary and possible' (IEA, 2009). The New Climate Economy (NCE) reports more recently have reframed the measures required for climate-change mitigation in the language of opportunity (NCE, 2014, 2015), and 'green growth'.

Academic interest in green growth strategies dates largely to the turn of the millennium (e.g. Ekins, 1999). By 2012 the combination of high commodity prices, financial crisis and upgraded risk assessments associated with climate change caused the concept of green growth to be adopted as a full-blown political and economic strategy by the major multilateral development banks and the OECD (Jacobs, 2012).

Thus, between Copenhagen (COP 15) and Paris (COP21) there was an important change in the mood with which the international climate-change negotiations were conducted. Instead of 'burden sharing' the language was now of 'low-carbon opportunity'. In part, this was because the baselines against which the costs of climatec hange mitigation are compared had changed. Many estimates of cost of mitigation are 'panglossian' in that they assume 3% GDP growth into the future, even when there is no significant emissions reduction, and therefore substantial projected climate change. Such optimistic assessments of future GDP growth remain mainstream. The IEA, for example, continues to project global GDP to grow at an average annual rate of 3.5% in the period 2013–2040 across each of its WEO 2015 scenarios (IEA, 2015, Table 1.2, p. 37). But such projections assume away one of the main causes of concern about climate change – that it will not have a significant negative impact on economic activity.

The more optimistic discourse about climate-change mitigation derives partly from the fact that the policy process is beginning to look critically at the implicit costs of baseline scenarios in terms of what happens if there is no substantial mitigation of climate change. The attack on the 'baseline' is summarized by Stern (2016):
So the business-as-usual baseline, against which costs of action are measured, conveys a profoundly misleading message to policymakers that there is an alternative option in which fossil fuels are consumed in ever greater quantities without any negative consequences to growth itself.

Partly, the present green growth policy discourse is presenting the prospect of four (win-win-win-win) outcomes: (1) lower energy costs, (2) higher economic growth and employment, (3) reduced impacts from climate change, and (4) co-benefits such as reduced air pollution. Bottom-up analyses of the cost of financing the low carbon pathway have been estimated at about 2–4% of expected capital expenditure up to 2030, with the net increase in financing costs being perhaps 0.7–2.3% of total financing for global capital expenditures (Beinhocker & Oppenheim, 2016). Such costs are still substantial, and it is possible to overdo the win-win rhetoric, but even the high end of this range is around half of the costs to GDP associated with high oil prices in the period 2004– 2008. In financial and economic terms, it is now clear that in many regions and applications, properly costed, climate-change mitigation technologies are becoming increasingly affordable.

The discourse around decarbonization is changing and this is sending a different message to markets from even a few years ago: fossil fuels are the energy source of the past; the future is low-carbon (actually needs to be zero and negative carbon if the 2°C target, let alone 1.5°C, is to be met).

Genuine 'Green Growth' (i.e. renewables and energy efficiency) is now the strategic decarbonization imperative. Developing countries will not deliver on their Intended

Nationally Determined Contributions (their emission reduction commitments in the Paris Agreement), let alone make them more stringent, if doing so is perceived to constrain those countries' economic development.

3.1 The falling cost of renewables

There has been a rapidly changing technological landscape around renewables. Increased public funding for renewable energy R&D, diffusion, and deployment has led to a virtuous circle of cost reductions, further policy support, and technological innovation that has achieved a colossal reduction in the cost of renewable energy sources in the last decade or so (Trancik, 2014). The levelized cost of solar (PV) electricity, for example, halved between 2010 and 2014 (Ekins, Bradshaw, & Watson, 2015; IRENA, 2014, p. 12). Simultaneously, global patents in the field of renewable energy have increased dramatically in the last decade. Cost reductions in solar technologies mean that it some parts of the world it has already achieved parity with electricity from fossil fuels. Coupled with policy makers increased recognition of the air pollution costs of fossil fuels, the change in mood at COP21 around climate-change mitigation was palpable. Perceptions about baseline policy and technological trajectories have a major influence on market dynamics. Several developments at or just before COP21 show how it continues to swing away from fossil fuels and towards renewables at a pace. An Indian initiative, the International Agency for Solar Technologies and Applications, involving some 120 mainly tropical countries, was announced at COP21 and aims to reduce the costs of solar technology through massively increased deployment around the world. Also at COP21 a number of the world's richest individuals set up the Breakthrough Energy Coalition to accelerate the development of innovative low-carbon technologies, while 21 governments established Mission Innovation to double the amount of public money going into clean energy innovation.

Rapid deployment of renewable energy technologies (together with on-going energy efficiency improvements) was in part responsible for global carbon emissions remaining relatively flat in 2014/2015 despite an increase in global energy consumption. According to REN21, renewables (predominantly wind, solar PV, and hydro power) represented approximately 58.5% of net additions to global power capacity in 2014 (2015, p. 17).

3.2 Incremental costs versus incremental investment

The present value of operating cost savings from reduced fossil-fuel consumption should be taken into account when evaluating investments in energy efficiency and renewables. Climate-finance analyses can focus on either incremental investment or incremental costs (Haites, 2011). Generally incremental investment analysis is much simpler than incremental cost analysis as data on lifetimes, future energy prices, operating costs, and discount rates are not required.

Renewables have far lower operating costs than fossil-fuel plants, and investments in energy efficiency will also reduce energy-related expenditures in the future (provided they are accompanied by policies to prevent the rebound effect). This is clearly relevant to the overall economic impact of any additional capital costs incurred by climate mitigation investments. Haites (2011, p. 965) points out that the 'estimated incremental cost is usually much lower than the corresponding incremental investment'.

This difference in operating costs between a low-carbon and fossil-fuel energy system means that the scale of annual expenditure on energy and fuel as a proportion of GDP should also be considered when the financial implications of these different systems are being compared. There are currently no officially published data at a country by country level on energy expenditure as a percentage of GDP. As a share of overall global GDP, energy expenditures have been estimated at around 8–9% (IER, 2010). In line with rates of energy consumption, the majority of this expenditure is currently on fossil fuels. Some *ad hoc* figures are available for individual countries. For example, in the US it was as high as 13.7% in 1981 and stood at 8.3% in 2010 (EIA, 2011). In the UK, energy as a proportion of GDP has reduced significantly from around 9% in the late 1970s to 2.8% in 2014 (UK DECC, 2015). Assuming globally as a whole that energy expenditure lies on average somewhere between 3% and 10% depending on energy prices, this would give an upper and lower first guess at total global expenditure flow on energy to be of the order of US$2.3–7.8 trillion per year.

Surprisingly low estimates of the overall cost of decarbonization in the longer term are possible because of the size of current expenditures on the fossil-fuel economy. For example, according to NCE (2014, pp. 3–5)

A shift to low-carbon infrastructure will have an additional impact, changing both the timing and mix of infrastructure investment. A low-carbon transition across the entire economy could be achieved with only 5% more upfront investment from 2015-2030 … Overall, the net incremental infrastructure investment needs from a low-carbon transition could be just US$4.1 trillion, if these investments are done well.

While net cost or incremental methods for assessing investment requirements are contentious (Olbrisch et al., 2011), such remarkably small estimates indicate how perceptions about the costs and benefits of emissions reduction have begun to change in recent years.

3.3 Environmental fuel taxation

There are many unpriced externalities associated with fossil-fuel energy consumption. Interest in environmental fuel taxation based on full cost accounting is rising. The international policy landscape is moving towards including in calculations of energy subsidies not just the pre-tax producer and consumer subsidies but estimates that take account of the full costs of fossil-fuel combustion to society, including their full life cycle environmental costs (IMF, 2015).

In 2015 IEA estimated that the value of direct financial fossil-fuel subsidies worldwide was US$493 billion (IEA, 2015, p. 96). In contrast, the IMF (2015) estimated total energy subsidies (i.e. including external environmental costs) to be US$4.9 trillion (6.5% of global GDP) in 2013, and projected them to reach US$5.3 trillion (6.5% of global GDP) in 2015. This provides another reference point for the US$100 billion. Fossil-fuel energy subsidies (including external environmental costs) are in the order of 53 times larger than the US$100 billion climate finance number.

According to the IMF, regionally, pre + post-tax subsidies vary as a function of share of coal and petroleum in primary energy use as well as exposure of population to combustion emissions. Subsidies reach as much as 17–18% of GDP in CIS (Commonwealth of Independent States) and Emerging and Developing Asia. In MENA (Middle East, North Africa, Afghanistan, and Pakistan) they amount to 13%, predominantly related to the use of petroleum.

According to the IMF:
Eliminating post-tax subsidies in 2015 could raise government revenue by $2.9 trillion (3.6% of global GDP), cut global CO2 emissions by more than 20%, and cut premature air pollution deaths by more than half. After allowing for the higher energy costs faced by consumers, this action would raise global economic welfare by $1.8 trillion (2.2% of global GDP). (2015, p. 6)

4. Policy imperatives and approaches: using billions to unlock trillions

Strong, stable, and sustained public policy is required to achieve the deployment of low-carbon energy sources at the required rate to stay within the global temperature limits set by the UNFCCC. Incremental investment requirements and policy ambition/effectiveness are interdependent. Investment needs assessments make assumptions about the baseline policy landscape. Policy makes assumptions about finance and investment needs, opportunities, and gaps. Low-cost incremental investment scenarios such as those by the NCE (2014, 2015) to meet climate goals require ambitious and effective climate policies. They not only require the rapid wholesale transformation of (for example) the electricity system but also substantial system-level impacts as a result of billions of individual consumer, investor, company micro decisions favouring lower energy, higher renewable futures, higher climate-resilient futures. Climate policy and incremental investment is a chicken and egg problem (Schmidt-Traub, 2015).

Climate change is just one part of a broader landscape of investment required to achieve sustainability goals. The OECD neatly summed up the overall policy challenge in achieving the SDGs as ‘using billions to unlock trillions’ (OECD, 2016c, p. 27).

Very similar typologies of options and policies appear time and again on how best to mitigate greenhouse gas emissions. Frequently, these policy typologies are threefold: carbon pricing; the stimulation of innovation and low-carbon technological development and deployment; and removing barriers to behavioural change (Grubb, Hourcade, & Neuhoff, 2014; Stern, 2007).

4.1 The need for consistent policy

The first priority for low-carbon policy to attract large-scale investment is that it should be long term, consistent, predictable, and transparent. The importance of this is illustrated by the reduction in investment in renewables brought about by the sudden policy changes by the UK government following its election in May 2015. Within a year, the UK, which had routinely topped the annual league table compiled by Ernst & Young of countries attractive to renewable energy investments had slid to 13th place (*Guardian*, 2016). Policy-driven transitions in energy systems are complex *in situ* experiments within path-dependent socio-technical systems. The need for consistent and stable policy environment has been expressed in many countries and by stakeholders including investors, suppliers, business users, policy makers (e.g. CBI, 2016).

4.2 The importance of carbon and fossil fuel prices and subsidies

The second important policy priority is that the prices of different energy sources reflect their full costs, requiring subsidies for fossil fuels to be removed and their prices to reflect their full environmental costs.

It needs to be recognized that an important consequence of an effective Post-Paris international policy regime would be even lower coal, oil, and gas prices. There are significant amounts of economically recoverable hydrocarbons and if the demand becomes constrained by climate policy – the price is likely to fall.

Private investment is playing and will play a major role in investments in the energy system, so investments will need to make a risk-reflective normal rate of return. The recent collapse in fossil-fuel prices has been rapid and deep and is having profound and complex impacts on the investment landscape. Low oil and gas prices help choke off investment in new fossil-fuel developments. However, low oil and gas prices, by making clean energy less competitive, can also deter or delay investment in clean energy that is intended to substitute for current fossil-fuel sources.

However, until consumers get used to low energy prices, there is a potential opportunity to introduce carbon pricing at a time when policy and political resistance to it may be lower. For example, a US$50 a tonne carbon tax introduced now, while significantly increasing the consumer price, would not raise fossil-fuel prices beyond the levels to which consumers were accustomed before 2014 – but this window of potential political feasibility of a carbon tax will fade with the memory of the high oil prices.

Given the underlying strength of demand for fossil fuels (oil and gas in particular) in all currently mainstream future energy projections, there will be at some stage a recovery in the oil price as supply tightens. In the absence of alternatives, higher fossil-fuel prices are necessary to balance anticipated supply with global demand. As the IEA (2015, pp. 48–49) puts it:

The relationship between the supply cost curves and oil prices is not straightforward, but the inference is that a price in the range of $80–120/barrel is likely to be required to enable supply to meet demand in the New Policies Scenario to 2040.

There is therefore much interest in ‘oil price trajectories’. More important perhaps are ‘carbon price trajectories’ that policy should be attempting to manage. Indeed future patterns in the investment landscape are all about the collisions of at least three inter-related price trajectories: oil, carbon, and the levelized costs of renewable/ low-carbon energy.

Carbon pricing is accelerating. According to World Bank and Ecofys (2016) carbon pricing is being applied to around 13% of global emissions – a threefold increase over the last decade. China's plans for a national emissions trading scheme commencing in 2017 will take this figure to 25%. As of mid-2015, carbon pricing (tax or cap-and-trade schemes) covered around 3.7Gt or 12% of global energy-related CO2 emissions with an aggregate value of US $26 billion (IEA, 2015, p. 41) – a 60% increase compared to 2014. The IEA's current 450 ppm policy scenario assumes CO2 prices in 2030 (in US $2014) in the range $100–140 per tonne in OECD countries with a lower range for the BRICS of US $75–120 per tonne. However, the 2°C pathway will require much more widespread and aggressive carbon pricing.

In 2015, the World Bank Group and the International Monetary Fund launched *The Carbon Pricing Panel* with heads of government and supported by private sector leaders to promote the use of effective carbon pricing policies. The following quote from World Bank Group President Jim Kong Kim neatly sums up the centrality of an effective carbon pricing regime within the overall frame of green growth strategies:

There has never been a global movement to put a price on carbon at this level and with this degree of unison. It marks a turning point from the debate on the economic systems needed for low carbon growth to the implementation of policies and pricing mechanisms to deliver jobs, clean growth and prosperity. The science is clear, the economics compelling and we now see political leadership emerging to take green investment to scale at a speed commensurate with the climate challenge. (Carbon Pricing Leadership, 2016)

4.3 The need for support for low-carbon technologies

In many ways it is remarkable that investment in renewable energy technologies has continued at high levels despite the collapse in fossil-fuel prices (BNEF, 2015). However, in the presence of widespread subsidies for fossil fuels, and the absence of systematic attempts to internalize their external costs, low-carbon energy sources are likely to be more expensive than high-carbon energy sources for some time. Under these circumstances, credible policy to support the low-carbon energy policy is essential. As already noted, such policy support needs to be consistent, predictable, and transparent.

Such policy support needs to include large research and development (R&D) programmes as well as a range of policies (Feed-in-Tariffs, portfolio targets, grants) for massive low-carbon deployment, to include renewables, nuclear, and carbon capture and storage, depending on national priorities, with predictable degression to reflect technological change (Grubb et al., 2014).

With all governments now committed to low-carbon technologies in principle, the economic prizes for successful commercialization of them are enormous. For example, solutions to the problems of electricity storage, revolutionizing the utility of intermittent renewables, and learning how best to combine energy system with information and communication technologies will create markets worth hundreds of billions of dollars. Similarly, with estimates that 60% of the urban infrastructure that will exist in 2050 still needs to be built (UNEP, 2013, p. 6), the economic opportunities for the pioneers of more sustainable urban forms are very great – but so are the potential carbon emissions if this urbanization proceeds along current trajectories.

4.4 The need for changes in behaviour

Finally, the low-carbon transition would be made much simpler if increased awareness about the threat of climate change, and the behaviours which contribute to it, led to more fundamental behavioural change. Two major relevant areas in this regard are the installation of energy efficiency measures in buildings, moves to reduce food waste and excessive meat consumption, and producer/consumer alliances to control deforestation and forest degradation.

The importance of the behavioural dimension is a reflection of the fact that climate-change mitigation is not only a function of policy. The energy transition is a complex multifaceted series of evolutions/adaptations (Armstrong et al., 2016). Coherent policy investment scenarios that take into account behavioural as well as technological change are now emerging. One example is a study by The Global Commission on the Economy and Climate on an investment scenario, comprising a set of practical recommendations, to achieve most of the emission reductions necessary to remain on the pathway to limiting global warming to 2°C by 2030 (NCE, 2015).

5. Conclusions

Currently there is no prospect of a *direct* global regulatory approach to limit fossil-fuel extraction and use. Therefore, to have a reasonable chance of fulfilling the goal of the Paris Agreement of limiting global temperature rise to less than 2°C, the global economy needs to rapidly develop non-carbon energy sources that are cheaper, cleaner (e.g. creating less air pollution), and more convenient than fossil fuels. This in turn requires an acceleration of public and private investment targeted at developing low-carbon energy technologies across the innovation curve. To address the wider goal of avoiding excessive damage from climate change to which the world is already committed, considerable investments in climate resilience are also required to achieve lower cost adaptation strategies.

The key message in this article is that current levels of climate finance are more than an order of magnitude smaller than anticipated baseline investment in the climate-related economy in the period up to mid-century. The current scale of climate finance is measured in the US$10–100 billion per year whereas (a) financial flows in energy and agricultural systems, (b) fossil-fuel subsidies (c) welfare losses, and (d) potential welfare benefits from investments in a low-carbon development pathways – are measured in the US$ trillions per year.

There are some pertinent recent historical examples of countries such as China ramping up investments in renewables (to 36% of the global total invested in renewables in 2015) through coherent policy packages (e.g. REN21, 2016). The challenges of scaling up climate finance to the levels required are awesome and unprecedented. But the benefits of doing so are also very large, promising enhanced innovation in clean technologies and the growth of huge new industries from low-carbon investments, and enhanced economic growth and great increases in human welfare from the removal of fossil-fuel subsidies and the internalization of the externalities from their combustion.

The Paris Agreement came about because there was increased realization of these benefits among policy makers. In some cases, the policies to realize current commitments are lacking. Moreover, current commitments do not yet match the targets in the Paris Agreement.

The technology and finance levers to achieve the substantive outcomes desired by the Paris Agreement are available. Recognition that deploying them entails more benefits than costs is growing. What is now required is that policy makers have the courage to act on this recognition in the limited time that is left for the Paris targets to remain within reach.

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